

What is claimed is:

1. A method of synthesizing uniform nanorods of metals, alloys, metal oxides, metal nitrides, metal pnictides, and metal chalcogenides, comprising the steps of;

5 reacting a metal precursor and a surfactant in a solvent to form a metal-surfactant complex solution;

injecting said metal-surfactant complex into a solution containing a surfactant and a reagent at high temperature using a syringe pump at a constant injection rate to form a reaction mixture;

10 reacting said reaction mixture to form said nanorods;

separating and precipitating said nanorods in the reacted mixture by adding a poor solvent; and

retrieving said nanorods by centrifuging.

15 2. The method of claim 1, wherein said metal precursor is selected from a group of (a) organometallic compounds including typically iron pentacarbonyl  $[\text{Fe}(\text{CO})_5]$ , ferrocene, cobalt tricarbonylnitrosyl  $[\text{Co}(\text{CO})_3(\text{NO})]$ , dicobalt octacarbonyl  $[\text{Co}_2(\text{CO})_8]$ , chromium hexacarbonyl  $[\text{Cr}(\text{CO})_6]$ , nickel tetracarbonyl  $[\text{Ni}(\text{CO})_4]$  and dimanganese decacarbonyl  $[\text{Mn}_2(\text{CO})_{10}]$ , (b) metal acetylacetonate compounds including typically  
20 iron acetylacetonate  $[\text{Fe}(\text{acac})_3]$ , cobalt acetylacetonate  $[\text{Co}(\text{acac})_3]$ , barium acetylacetonate  $[\text{Ba}(\text{acac})_2]$ , strontium acetylacetonate  $[\text{Sr}(\text{acac})_2]$ , platinum acetylacetonate  $[\text{Pt}(\text{acac})_2]$  and palladium acetylacetonate  $[\text{Pd}(\text{acac})_2]$ , and (c) metal alkoxide compounds including typically titanium tetraisopropoxide  $[\text{Ti}(\text{OC}_3\text{H}_7)_4]$  and zirconium tetrabutoxide  $[\text{Zr}(\text{OC}_4\text{H}_9)_4]$ .

25 3. The method of claim 1, wherein said metals used for the precursors are

selected from typically iron [Fe], cobalt [Co], nickel [Ni], chromium [Cr], manganese [Mn], barium [Ba], strontium [Sr], titanium [Ti], zirconium [Zr], platinum [Pt], palladium [Pd] and the groups II through X transition metals in particular.

4. The method of claim 1, wherein the ligands associated with said precursors are typically carbonyl [CO], nitrosyl [NO], cyclopentadienyl [C<sub>5</sub>H<sub>5</sub>], acetate, aromatic compounds and alkoxide family.

5. The method of claim 1, wherein said metal salts used as precursors are

typically iron(III) chloride [FeCl<sub>3</sub>], iron(II) chloride [FeCl<sub>2</sub>], iron(II) sulfate [FeSO<sub>4</sub>], iron(III) nitrate [Fe(NO<sub>3</sub>)<sub>3</sub>], cobalt(III) chloride [CoCl<sub>3</sub>], cobalt(II) chloride [CoCl<sub>2</sub>], cobalt(III) nitrate [Co(NO<sub>3</sub>)<sub>3</sub>], nickel(II) sulfate [NiSO<sub>4</sub>], nickel(II) chloride [NiCl<sub>2</sub>], nickel(II) nitrate [Ni(NO<sub>3</sub>)<sub>2</sub>], titanium tetrachloride [TiCl<sub>4</sub>], zirconium tetrachloride [ZrCl<sub>4</sub>], hydrogen hexachloroplatinate(IV) [H<sub>2</sub>PtCl<sub>6</sub>], hydrogen

hexachloropalladiate(IV) [H<sub>2</sub>PdCl<sub>6</sub>], barium chloride [BaCl<sub>2</sub>], barium sulfate [BaSO<sub>4</sub>], strontium chloride [SrCl<sub>2</sub>] and strontium sulfate [SrSO<sub>4</sub>], whereby these metal salts consist of various metals including typically iron [Fe], cobalt [Co], nickel [Ni], chromium [Cr], manganese [Mn], barium [Ba], strontium [Sr], titanium [Ti], zirconium [Zr], platinum [Pt], palladium [Pd], and anions including typically chloride [Cl<sup>-</sup>], nitrate [NO<sub>3</sub><sup>-</sup>], sulfate [SO<sub>4</sub><sup>2-</sup>], phosphate [PO<sub>4</sub><sup>3-</sup>] and alkoxides.

6. The method of claim 1, wherein said nanorods of alloys and multi-metallic oxides are formed using mixtures of two or more metal precursors selected from the list in claim 2 instead of using a metal precursor.

7. The methods of claim 1, wherein said surfactant is selected from (a) cationic

surfactants including typically alkyltrimethylammonium halides such as cetyltrimethylammonium bromide, (b) neutral surfactants including typically oleic acid, trioctylphosphine oxide (TOPO), triphenylphosphine (TPP), and trioctylphosphine (TOP), alkyl amines,  $\text{RNH}_2$ , where R is alkyl groups with 3-18 carbons, such as  
5    oleylamine, octylamine, and hexadecylamine, and trialkylamine and alkyl thiols, and (c) anionic surfactants including typically sodium alkyl sulfates and sodium alkyl phosphates, and mixtures of two or more surfactants listed above.

8.    The methods of claim 1, wherein said solvent is selected from typically (a)  
10    ethers such as octyl ether, butyl ether, hexyl ether and decyl ether, (b) heterocyclic compounds such as pyridine and tetrahydrofuran (THF), (c) aromatic compounds such as toluene, xylene, mesitylene, benzene, (d) dimethyl sulfoxide (DMSO) and dimethylformamide (DMF), (e) alcohols such as octyl alcohol and decanol, (f) hydrocarbons such as heptane, octane, decane, dodecane, tetradecane and  
15    hexadecane, and also (g) water.

9.    The method of claim 1, wherein said metal-surfactant complex is formed at a temperature between 20 °C and 200 °C.

20    10.    The method of claim 1, wherein the molar ratio of said metal precursor to said surfactant is in the range between 1:0.1 and 1:100.

11.    The method of claim 1, wherein for synthesizing nanorods of metal chalcogenides said reagent is selected typically from elemental sulfur ( $\text{S}_8$ ), selenium  
25    (Se), tellurium (Te), trioctylphosphine selenide (TOPSe), trioctylphosphine sulfide (TOPS) and trioctylphosphine telluride (TOPTe).

12. The method of claim 1, wherein for synthesizing nanorods of metal oxides said oxidant is selected typically from oxygen ( $O_2$ ), hydrogen peroxide ( $H_2O_2$ ), and amine N-oxide such as pyridine N-oxide and trimethylamine N-oxide.

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13. The method of claim 1, wherein for synthesizing metal nanorods said reductant is selected typically from sodium borohydride ( $NaBH_4$ ), lithium aluminum hydride ( $LiAlH_4$ ), lithium triethylborohydride (super-hydride,  $LiB(C_2H_5)_3H$ ), tetramethylammonium borohydride ( $(CH_3)_4NBH_4$ ) and hydrogen gas.

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14. The method of claim 1, wherein said metal-surfactant complexes are injected into a solution at a temperature between  $0\text{ }^{\circ}C$  and  $400\text{ }^{\circ}C$ .

15. The method of claim 1, wherein said metal-surfactant complex is injected into a solution using a syringe pump at an injection rate between 1 mL/hr and 100 mL/hr.

16. The method of claim 1, wherein said reaction process of said reaction mixture is carried out at a temperature between  $0\text{ }^{\circ}C$  and  $400\text{ }^{\circ}C$ .

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17. The method of claim 1, wherein said reaction process of the reaction mixture is carried out for a time period between 1 minute and 72 hours.